New view on the quantum Hall phase diagram of bilayer graphene

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Bilayer graphene exhibits a rich phase diagram in the quantum Hall (QH) regime, arising from the interplay of the spin, valley, and orbital degrees of freedom. In particular, at very high magnetic fields, a perpendicular electric field (D) drives transitions between valley-unpolarized and valley-polarized states in several QH phases. In this study [1] we explore the behavior of these transitions as the magnetic field B is reduced, focusing on the phases in the filling-factor range 1< u<2. We find that as B is lowered, the variation of the critical electric field (D*) with filling factor exhibits a puzzling change of trend, from increasing to decreasing; near u=2, D* may even vanish if B is sufficiently small. We present a theoretical model for the lattice-scale interactions which correctly accounts for these surprising observations; contrary to earlier studies, it involves finite-ranged terms comprising both repulsive and attractive components. Furthermore, we (theoretically) analyze the nature of the u=2 state as a function of B and D, and find that a valley-coherent phase may emerge in the D D* regime. This suggests the existence of a Kekule bond-ordered phase at low magnetic fields, similarly to the phases recently observed in the u=0 phase through STM measurements.

[1] Udit Khanna, Ke Huang, Ganpathy Murthy, H. A. Fertig, Kenji Watanabe, Takashi Taniguchi, Jun Zhu and Efrat Shimshoni, Phys. Rev. B108 (2023) L041107.